OXYGEN IN WATER

by Roger Zimmerman, Ph.D.

Why do we measure it?

A short answer to this question is that fish and other aquatic creatures need oxygen to stay alive. Unlike us, these creatures breathe oxygen not from the air but from gas that is dissolved in water.

Oxygen in respiration and photosynthesis.

Most plants and animals, including bacteria, need oxygen for *respiration*. Through respiration, oxygen releases energy (by *oxidation*) from organic compounds for life-supporting *metabolism*. Metabolism involves the chemistry of body maintenance, movement, growth and reproduction. Byproducts of respiration are carbon dioxide and water. Respiration can be described by oxidation of the simple sugar glucose. The equation is:

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$$

+ energy in 36 ATP,

or, in common terms,

one *sugar* molecule
plus six *oxygen* molecules

yields

six molecules of *carbon dioxide*
plus six *water* molecules

and

energy for metabolism.

Animals must eat plants or other animals to get the organic compounds they need for metabolism. For this reason, animals are called *heterotrophs*. Most plants make their own organic compounds through *photosynthesis*. Photosynthesis uses the energy from sunlight and carbon dioxide gas to produce sugar through a process that is the reverse of respiration. Oxygen is the byproduct of photosynthesis. Plants that photo-synthesize are *autotrophs*. The processes of respiration and photosynthesis are the same whether they occur in the air (the *atmosphere*) or in water (the *aquatic* environment).

photo by Carmen Fitzgerald

TEST monitors being trained to perform dissolved oxygen test.

How does oxygen get into water?

Dissolved oxygen (DO) in water comes from the atmosphere and aquatic plants. Oxygen enters water from the atmosphere by *diffusion*. The amount of oxygen diffused into water is in proportion to other gases in the atmosphere. How fast atmospheric oxygen moves from the top to the bottom of the *water column* depends on the diffusion rate and how actively water is mixing (the *advection* rate). Turbulence from waves and currents increases advection. When water is calm, or when the water column is layered in masses (*stratification*) of different densities, the movement of oxygen through water is slowed.

The total amount of gas soluble in water, including oxygen and all other gases, depends upon water temperature and density. Less gas can be dissolved when water temperatures and densities are low. Salinity and temperature both affect water density. Cold water and high salinity water are more dense than warm water and low salinity water. Therefore, the highest DO values are expected in water that is cold and fresh. Conversely, the lowest DO values are expected in warm, high salinity water. DO is said to be at *saturation* when the amount of dissolved gas in surface water is at equilibrium with the atmosphere. The DO saturation point varies, depending upon atmospheric pressure, temperature and salinity. When the amount of DO exceeds this point the water is *supersaturated*. Sometimes when shallow water is supersaturated, dissolved gases come out of solution and bubbles form in the water column.

In nature, supersaturation of oxygen in water can take place where aquatic plant life is abundant and an excessive amount of oxygen is produced from photosynthesis. Supersaturation commonly occurs during warm sunny days in shallow water. Under these conditions, sunlight stimulates photosynthesis and warm temperatures decrease the capacity of water to hold dissolved gases. In areas with submerged aquatic vegetation, such as seagrass and macroalgae beds, it is not uncommon to see gases bubble out of solution on summer days.

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Oxygen

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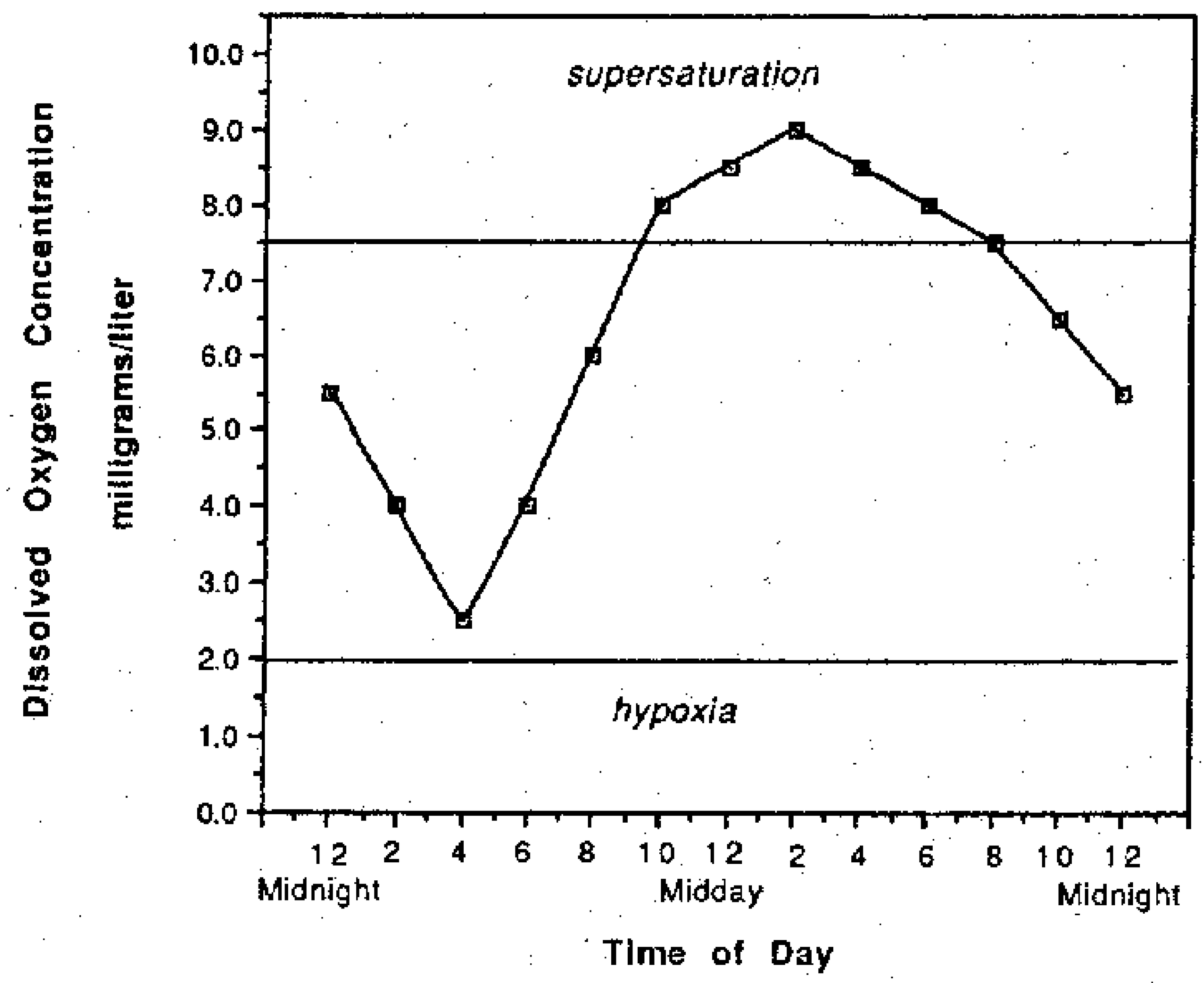
Diurnal Cycle of Dissolved Oxygen In Shallow Water



Measurement of DO

Since DO in water is quite variable and life depends on oxygen for respiration, it is important that we routinely monitor DO levels in nature. Measurement of DO is expressed in terms of how much oxygen is dissolved in a given amount of water, such as milliliters or milligrams of oxygen per liter of water (abbreviated as *ml/l* or *mg/l*). It is also common to see parts per million by weight (*ppm*) used, which has the same numerical value as mg/l. For precise measurements, an analytical chemistry procedure called the Winkler Titration Method is required. Most field measurements of DO were done by this method in the past. But now, field measurements of DO are usually accomplished with electronic meters that display an amplified signal from a membrane covered polarographic sensor. These instruments provide accurate measurements, so long as they are properly calibrated, the probes are kept clean, and the readings are adjusted for effects of atmospheric pressure, temperature, and salinity.

Dissolved oxygen in estuarine waters varies substantially between night and day. Lowest DO values are recorded at night. This happens because plants and animals are respiring and depleting oxygen throughout the night without addition of new oxygen from photosynthesis. In early morning hours, before sunrise, it is common for DO to fall to near a level causing respiratory stress. This environmental condition is called *hypoxia*.

Hypoxia exists when DO is depleted to below 2 ppm (or mg/l). When the environment becomes *anoxic* (meaning without oxygen) respiration can no longer occur. These conditions sometimes happen because advection of oxygen from the atmosphere alone is not enough to compensate for losses of oxygen due to respiration at night. Normally, when sunlight returns during the day, additional oxygen from photosynthesis more than compensates for nighttime losses and the DO values rise. This 24-hour rise and fall of oxygen, from supersaturation to near hypoxia, is a *diurnal cycle*.

Effects of DO depletion on aquatic animals

If oxygen is depleted to the point that conditions become anoxic, animals that cannot adjust or get away die quickly. When this happens, the aquatic community is disturbed by a *mass mortality*. Sometimes hypoxia or anoxia occurs when estuarine waters stratify. This can happen when a layer of fresh or warm water overlies saline or cold water and the bottom water is cut off from advection from the surface. In such cases, respiration consumes oxygen at the bottom faster than it is replenished. When respiration rates are high and stratification persists, oxygen depletion becomes severe. This can occur after heavy rainfall during warm months when freshwater runoff is warm and estuarine waters are cooler. During these periods, wave action and tidal currents may not be enough for vertical mixing.

Pollution may cause oxygen depletion by adding too many nutrients to the water. In such cases, both photosynthesis and respiration are overstimulated and the swing of DO during the diurnal cycle becomes extreme. Eventually, water simply cannot hold enough DO to accommodate the increase in respiration at night. Anoxia then occurs, mass mortality takes place and the system crashes. This process is called *eutrophication.*

Another similar situation results when too much organic matter is in the water and microorganism activity becomes exceedingly high. The amount of oxygen needed for microorganisms to degrade organics in water is the *biochemical oxygen demand* (*BOD*). High BOD is why we remove organic materials from sewage and industrial outfalls. Dredged harbors and dead-end channels can also cause anoxia in bottom waters. This happens when dredged areas, deeper than surrounding bottom, are poorly flushed by tidal currents. The resulting stratification frequently leads to anoxia.

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Suggested Further Reading:

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